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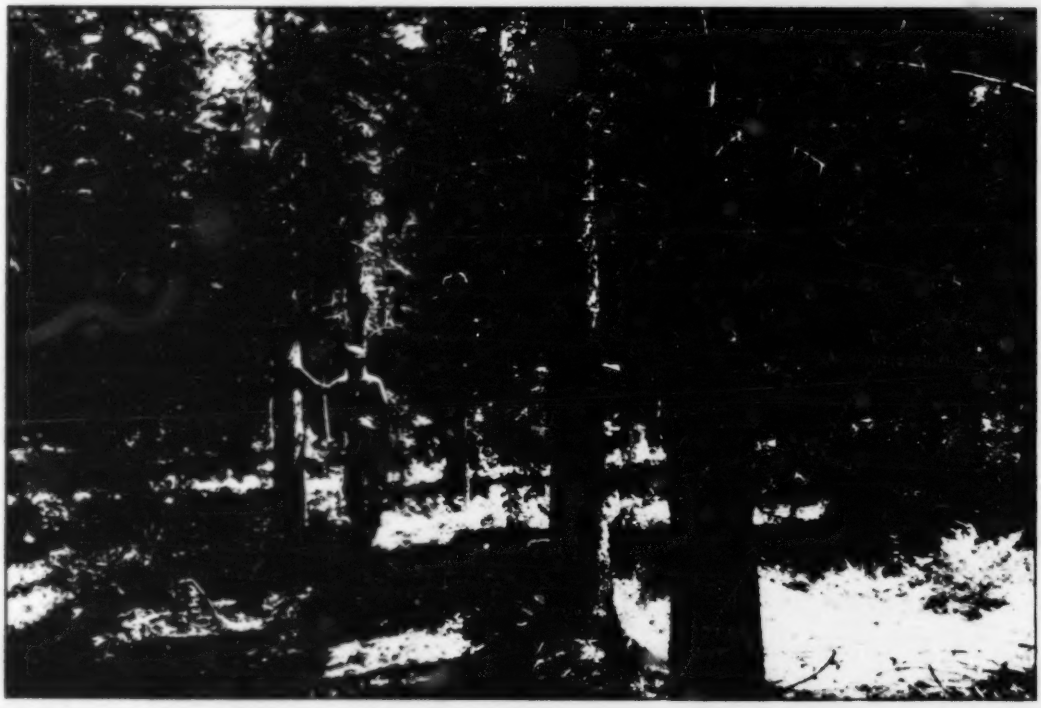
Plantation white spruce variable density volume and biomass yield tables to age 60 at the Petawawa National Forestry Institute

A.B. Berry

Information Report PI-X-71
Petawawa National Forestry Institute



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Cover: White spruce plantation at age 44 years at the Petawawa National Forestry Institute (planted at 2.13 x 2.13 m; thinned to 18.36 m^2/ha at ages 32 and 44).

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ABSTRACT

Recent remeasurements of sample plots in white spruce plantations at the Petawawa National Forestry Institute were used to update and revise previously published yield tables. Those presented here cover 20 to 60 years from planting by 5-year age classes, six planted spacings, and five site index classes. The data shown for each site index-age-spacing combination are dominant height, average height, number of trees, mean diameter, total basal area, total volume, merchantable volume, mass of total tree above ground, mass of main stem including bark, and mass of merchantable stem including bark.

RÉSUMÉ

De nouvelles mesures ont été prises dans des placettes d'échantillonnage établies dans des plantations d'épinettes blanches à l'Institut forestier national de Petawawa, et on s'en est servi pour mettre à jour et réviser des tables de production publiées antérieurement. Les tables présentées ici couvrent la période de 20 à 60 ans après la plantation et sont établies par classes d'âge de cinq ans pour six espacements à la plantation et pour cinq classes d'indice de station. On donne, pour chaque combinaison d'indice de station, d'âge et d'espacement, la hauteur dominante, la hauteur moyenne, le nombre d'arbres, le diamètre moyen, la surface terrière totale, le volume total, le volume marchand, la masse de la partie aérienne totale des arbres, la masse de la tige principale avec écorce et la masse de la tige marchande avec écorce.

PLANTATION WHITE SPRUCE VARIABLE DENSITY VOLUME AND BIOMASS YIELD TABLES TO AGE 60 AT THE PETAWAWA NATIONAL FORESTRY INSTITUTE

INTRODUCTION

Although there is now no world shortage of oil, it is inevitable that supplies of this non-renewable resource will become both scarcer and more expensive in the future. In preparation for the time when oil will no longer be an economical fuel, Canada has been exploring the use of renewable resources, including forest biomass, as alternative energy sources. Data are now available to revise and extend the white spruce (Picea glauca (Moench) Voss) yield tables (Berry 1978) to age 60 years from planting. In addition, the tables have been expanded to include the mass of the aboveground portion of the stand.

The tables are based on data from unthinned white spruce plantations at the Petawawa National Forestry Institute. Only those stands reflecting high initial survival, with virtually all the subsequent mortality due to intraspecific competition, have been used for this purpose.

PLANTATIONS

The white spruce plantations which form the basis for this report total about 32 hectares at the Petawawa National Forestry Institute. The oldest plantation was established in 1922. Most planting sites were old fields, and soils include water-laid sands, lacustrine silt loams, and sandy and loamy tills. Survival up to 30 years of age was generally in excess of 75 per cent.

Four main pests have caused various degrees of damage in these plantations. An outbreak of spruce budworm (Choristoneura fumiferana Clem.) in the late 1960s and early 1970s was successfully controlled on research areas using insecticides. A root rot (Armillaria mellea (Vahl ex. Fr.) Kummer) has killed potential crop trees at scattered points throughout the plantations. A stem canker Cytospora kunzei Sacc. is also prevalent and recurs in managed plantations even after thinning infected trees. Nevertheless, it is observed to be self-limiting, and is not considered a serious threat at Petawawa (Stiell 1986).

The most serious disease that has affected these plantations is the root rot Ionatus tomentosus (Fr.) Gilbertson (formerly Polyporus tomentosus Fr.), which is a widespread problem in the boreal forest and spreads by root-to-root contact (Whitney 1977). Death of trees often occurs in groups and there does not seem to be natural immunity. All sizes of trees can be affected, although

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the smaller ones succumb more quickly. The fungus grows slowly, taking at least 15 to 20 years to kill a tree after infection. At PNFI the disease does not usually appear in plantations less than 25 or 30 years old. As it is not known whether the pattern of mortality (age at onset, amount, etc.) is similar throughout eastern Canada, it was decided that sample plots affected by I. tomentosus would not be included for growth and mortality calculations.

A full description of the plantations, including their establishment, sites, and early development is given by Stiell (1955).

METHODS

In the preparation of these yield tables the basic assumptions were:

1. That dominant height of a stand is independent of spacing.
2. Dominant height is a reflection of the combination of site and age.
3. For a given dominant height the number of trees is primarily dependent on the initial planted spacing and is not related to age and site.

Density

In this paper, density levels are discussed in terms of both number of trees per hectare and square spacing, which is the generally accepted term used in plantation work. The equivalent values are as follows:

Spacing class (m)

mid point	1.25	1.50	1.75	2.00	2.50	3.00
range	1.13-1.37	1.38-1.62	1.63-1.87	1.88-2.12	2.38-2.62	2.88-3.12

Trees per hectare

mid point	6400	4444	3265	2500	1600	1111
range	7900-5289	5288-3787	3786-2844	2843-2215	1772-1451	1209-1024

In all calculations the spacing equivalent to trees/ha was expressed to the nearest hundredth of a metre, eg. 2550 trees/ha is equal to a spacing of 1.98 x 1.98 m.

Sample plots

Data for this paper were obtained from 46 permanent sample plots in plantation areas of high survival. Each plot had been measured from one to five times. On each plot individual tree records were kept (made possible by numbering and tagging each tree), and at each measurement stand tables were prepared. The data on numbers of trees, average diameter, dominant height, and total volume were converted from imperial measurements to metric equivalents. The following are the ranges of values in plantation data used:

Age from planting (years)	12 - 60
Trees/ha	5214 - 1730
Equivalent spacing (m)	1.38 - 2.40
Average dbh at 1.37 m (cm)	4.6 - 21.8
Dominant Height (m)	4.4 - 23.8
Average Height (m)	3.4 - 21.3
Basal Area (m^2/ha)	3.6 - 56.5
Total Volume (m^3/ha)	7.8 - 422.8

The variables in the yield tables were individually related to dominant height and spacing by regression methods, using the average values from each of the plots. Remeasurements from individual plots were treated as independent observations. The tables were then derived from the regression equations, which provided estimates for the required combinations of site, age, and spacing.

Site index curves

The site index curves showing height in feet for site indexes 50, 60, 70, and 80 feet at 50 years (Stiell and Berry 1973) were modified to show height in metres for site index classes 15, 18, 21, and 24 metres at age 50 years (Fig. 1).

Tree mortality

Mortality from intraspecific competition is a function of the growing space available to each tree, which is in turn dependent on spatial distribution, density, and height of trees.

The mortality data from all plots were pooled and, using a stepwise regression program, an expression relating mortality to a combination of stand height and density was derived:

$$M = -92.5299 + 0.6345\ NH \qquad R^2 = .692$$

where M is the number of trees dying for the next 1-metre increase in dominant height and NH is the present number of trees/ha x dominant height in metres/100.

Equation 1 was used to determine the rate of decrease in stand density with increase in dominant height for each spacing class. Starting with a stand height of one metre and the number of trees per hectare for that spacing class, the mortality was calculated. Progressively larger heights (in tenths of metres) were substituted in the expression until the death of at least one tree was indicated. The number of trees was then reduced and the dominant height increased by one metre and the mortality associated with the new NH was calculated using the mortality equation; this procedure was repeated until a dominant height of 24 m was reached. These calculated values for number of trees per hectare were plotted over dominant height, thus producing a series of curves based on different initial spacings (Fig. 2).

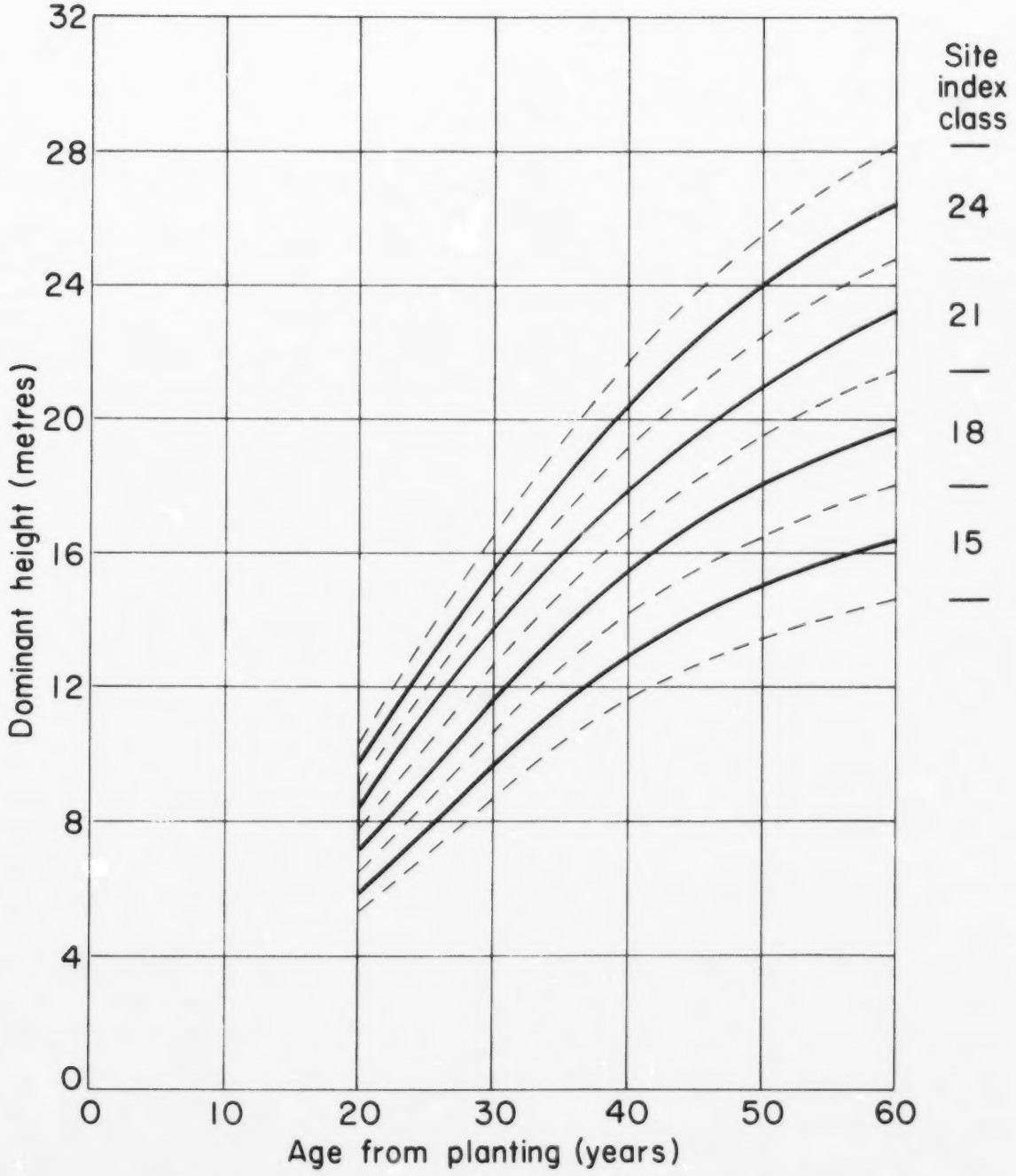

Figure 1. Site index curves, at base age of 50 years from planting, for planted white spruce.

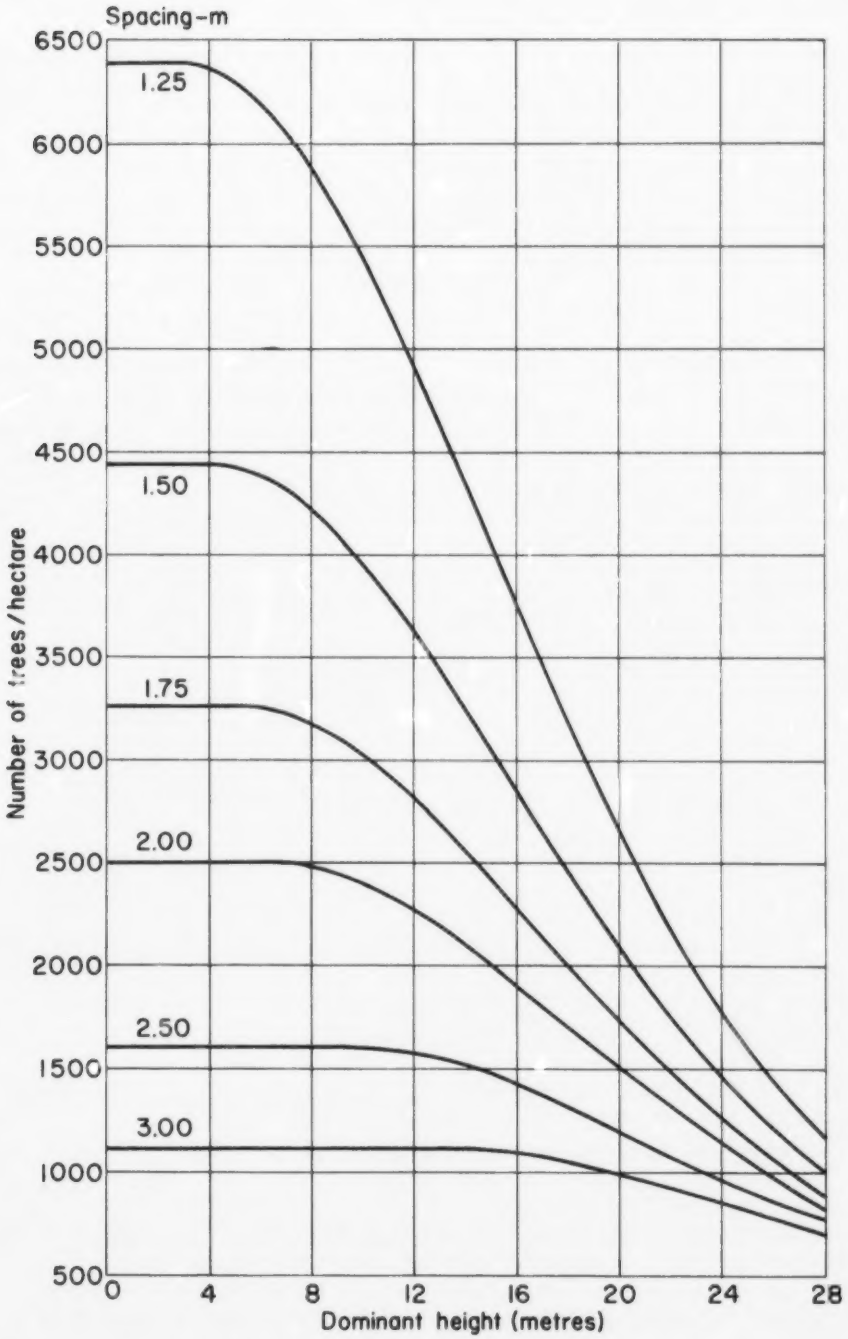

Figure 2. Relationship of number of trees to dominant height and initial spacing for planted white spruce.

The data for the onset of mortality as determined from regression (1) for each spacing were combined, and the following equation, relating height at which the first tree dies to initial number of trees, was derived:

$$Y = 1.02 + 14654.2/X \qquad R^2 = .999$$

where X is the initial number of trees per hectare and Y the dominant height at which the first tree has died from intraspecific competition, but not from external causes such as fire, wind, insect, or disease.

From this equation the forest manager can estimate when to expect mortality and thus schedule thinning in the stand if desired.

Basal area

A stepwise regression was used to derive basal area per hectare based on combinations of spacing and dominant height. The derived equation was:

$$BA = -7.8275 + 4.4811\ H/S \qquad R^2 = .896$$

where BA = basal area in m^2/ha
H = dominant height in m
S = $\sqrt{\text{spacing}}$ in m.

Mean stand diameter

The basal area per hectare was divided by the number of trees to calculate the tree of average basal area. The diameter corresponding to this basal area per tree was then entered in the table as the mean stand diameter.

Stand volume

The plot data on volume at different combinations of spacing and dominant height were analysed, also using stepwise regression techniques, and the following equation was derived:

$$Vt = -9.5226 + 1.6598\ (H/S)^2 \qquad R^2 = .945$$

where Vt = total volume in m^3/ha
H = dominant height in m
S = $\sqrt[3]{\text{spacing}}$ in m.

The merchantable volume to total volume ratios calculated previously, (Stiell and Berry 1973) and modified for metric usage (Berry 1978), were used to calculate merchantable volumes based on the different combinations of spacing and dominant height (Table 1). These ratios were originally calculated for a top diameter of 4 inches, larger than the usual 7 cm top diameter generally used with the metric system. Consequently, the merchantable volumes presented in these tables will be somewhat conservative.

Mass

The term "total mass" in this paper refers to the aboveground (oven-dry) mass of all white spruce trees and includes stem wood, bark on the main stem, branches, and needles. The mass per hectare for the total tree was found by multiplying total volume per hectare by the basic wood density of 386 kg/m^3 and then multiplying this amount by 1.299. The mass of the stem plus bark was calculated by multiplying the total volume by the basic wood density and then increasing this amount by 10.3 per cent to allow for bark. These conversion factors are from Alemdag (1983).

The merchantable stem plus bark was derived by applying the same percentage figures to the total stem plus bark mass as were applied to the total volume to arrive at merchantable volume.

Yield tables

Yield tables are predictive and show stand development with age. Tables 2 to 5 show yields for four site index classes at a base age from planting of 50 years. For each site index class, values are shown at 5-year intervals from 20 to 60 years for six initial planted spacings. The procedures for estimating the various parameters are as follows:

(a) Dominant heights at given ages were read from the site index curves (Fig. 1).

(b) Average height was obtained from the following regression:

$$Y = 0.9784 + 0.5349\ X + 0.0131\ X^2 \qquad R^2 = .976$$

where X = dominant height in m
Y = average height in m

(c) The number of trees per hectare was obtained from the numbers/height curve (Fig. 2).

(d) Basal areas were calculated from regression (3).

(e) Mean d.b.h. to the nearest 0.1 cm was calculated from numbers/ha and the basal area/ha as derived by (c) and (d).

(f) Total volumes were calculated from regression (4).

(g) The merchantable volume was calculated as a percentage of the total volume (Table 1).

(h) The total mass was calculated from total volume, basic wood density, and percentage of total tree of stem wood.

(i) The mass of stem plus bark was calculated from total volume and basic wood density plus the bark as a percentage of the stem wood.

(j) The mass for merchantable stem plus bark was taken as a percentage of the total stem plus bark mass (Table 1).

Most of the yield table values are based on data that fall within the limits of spacing and height. Bracketing of data in the tables indicate that these values are extrapolations with respect to spacing and/or dominant height.

Mean annual increment

The age at which mean annual increment (MAI) reaches a maximum for the different spacings and site index classes are shown in Table 6 for total and merchantable volume and for total mass, mass of stem plus bark, and mass of merchantable stem plus bark.

In general the age at MAI culmination increases with spacing for any site and decreases for any spacing with increase in site index. Love and Williams (1968) reported the same condition with MAI culminating between 50 and 60 years. The MAI for volume for most spacings and site index classes reaches a maximum at 50 years of age. On the other hand MAI for biomass of the close spacings for all sites reaches a maximum at 40 to 50 years and for the wider spacings at 50 to 55 years.

Management implications

Based on the data presented here, a rotation age ranging between 40 and 55 years (corresponding to age of peak MAI of merchantable volume) is recommended for plantations established for biomass or pulpwood production. Plantations destined for sawtimber products require longer rotation ages for a given spacing as larger minimum diameter limits have to be attained.

There are also limitations on rotation age imposed by root rot, the effects of which have not been included in this report's yield tables. Significant mortality caused by this or other damaging agents may necessitate thinning or early clear-cutting.

When determining the appropriate spacing for plantation establishment, the forester must consider site quality, wood product type and value, and desired rotation age. On poorer sites, spacing has little effect on age of maximum MAI of volume (Table 6), so it may be desirable to plant trees at closer spacings and produce pulpwood. On higher quality sites, culmination of MAI has a much greater age range between spacings. Thus, the manager must compare the economic and other benefits of a shorter rotation age for pulpwood production to those of a longer rotation age for sawtimber production.

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ACKNOWLEDGMENTS

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TABLES

Table 1. Percentages used to derive merchantable volume from total volume and merchantable stem plus bark mass from total stem plus bark mass

Dominant height	Planted spacing (m)					
	1.25	1.50	1.75	2.00	2.50	3.00
(m)	Percent of total					
6	8	17	22	29	36	41
8	45	53	60	65	75	79
10	61	66	72	77	84	89
12	72	75	80	83	88	92
14	79	81	84	86	90	92
16	83	85	86	87	90	92
18	85	86	88	88	91	92
20	85	87	88	89	91	92
22	85	87	88	89	91	92
24	85	87	88	89	91	92
26	85	87	88	89	91	92
28	85	87	88	89	91	92

Table 2. Yield table for unmanaged white spruce plantations (site index 15)

Age from planting years	Dominant height (m)	Average height (m)	Planted spacing (m)	Trees per ha (no.)	Mean d.b.h. (cm)	Basal area/ha (m^2)	Volume/ha Total (m^3)	Volume/ha Merch (m^3)	Mass/ha Total tree (t)	Mass/ha Total stem & bark (t)	Mass/ha Merch stem & bark (t)
20	5.9	4.6	(1.25	6204	5.66	15.6	40	2	17	14	1)
			1.50	4382	6.31	13.7	34	5	15	12	2
			1.75	3258	6.89	12.2	30	6	13	11	2
			2.00	2500	7.44	10.9	27	8	12	10	3
			(2.50	1600	8.41	8.9	22	7	9	8	3)
			(3.00	1111	9.23	7.4	18	7	8	7	3)
25	7.7	5.9	(1.25	5920	6.95	22.4	73	31	31	26	11)
			1.50	4237	7.75	20.0	64	32	27	23	12
			1.75	3192	8.50	18.1	58	32	25	21	12
			2.00	2487	9.19	16.5	52	32	23	19	12
			(2.50	1600	10.55	14.0	44	31	19	16	11)
			(3.00	1111	11.77	12.1	38	29	17	14	11)
30	9.6	7.3	(1.25	5520	8.21	29.2	116	68	49	42	25)
			1.50	3996	9.17	26.4	103	66	45	38	24
			1.75	3057	10.03	24.1	94	66	41	35	24
			2.00	2419	10.85	22.4	86	64	38	32	24
			(2.50	1600	12.42	19.4	74	61	33	28	23)
			(3.00	1111	13.96	17.0	64	56	29	24	21)
35	11.5	8.9	(1.25	5058	9.46	35.6	165	116	73	62	43)
			1.50	3696	10.57	32.4	148	108	67	57	42
			1.75	2865	11.52	29.9	135	105	62	52	41
			2.00	2303	12.42	27.9	125	102	58	49	40
			(2.50	1583	14.09	24.7	109	96	51	43	38)
			(3.00	1111	15.85	21.9	96	87	45	38	35)

Table 2. (cont'd)

Age from planting years	Dominant height (m)	Average height (m)	Planted spacing (m)	Trees per ha (no.)	Mean d.b.h. (cm)	Basal area/ha (m^2)	Volume/ha Total (m^3)	Volume/ha Merch (m^3)	Mass/ha Total tree (t)	Mass/ha Total stem & bark (t)	Mass/ha Merch stem & bark (t)
40	13.0	10.1	(1.25	4656	10.53	40.6	209	159	95	81	62)
			1.50	3422	11.69	36.7	187	146	86	73	57
			1.75	2690	12.71	34.1	171	140	80	68	56
			2.00	2185	13.65	32.0	159	135	75	64	54
			(2.50	1546	15.38	28.7	141	125	67	57	51)
			(3.00	1111	17.20	25.8	125	115	60	51	47)
45	14.1	11.1	(1.25	4320	11.31	43.4	240	190	112	95	75)
			1.50	3223	12.54	39.8	217	176	102	87	70
			1.75	2545	13.62	37.1	200	168	95	81	68
			2.00	2093	14.56	34.9	186	160	90	76	65
			(2.50	1508	16.31	31.5	166	149	81	69	62)
			(3.00	1110	18.13	28.7	149	137	74	63	58)
50	15.0	12.0	(1.25	4056	11.99	45.8	267	216	127	108	87)
			1.50	3038	13.29	42.1	242	201	117	100	83
			1.75	2427	14.37	39.3	223	192	110	93	80
			2.00	2010	15.35	37.2	209	182	104	88	76
			(2.50	1470	17.10	33.8	187	168	94	80	72)
			(3.00	1105	18.87	30.9	170	156	86	73	67)
55	15.7	12.6	(1.25	3850	12.55	47.6	288	239	139	118	98)
			1.50	2909	13.86	43.9	262	220	128	109	92
			1.75	2328	14.99	41.1	242	208	120	102	88
			2.00	1939	15.98	38.9	227	197	114	96	84
			(2.50	1437	17.73	35.5	205	187	104	88	80)
			(3.00	1097	19.47	32.7	186	171	95	81	75)
60	16.4	13.3	(1.25	3646	13.11	49.2	309	256	151	128	106)
			1.50	2770	14.46	45.5	281	239	139	118	100
			1.75	2230	15.60	42.6	261	227	131	111	97
			2.00	1866	16.63	40.5	246	216	124	105	92
			(2.50	1401	18.37	37.1	222	202	114	97	88)
			(3.00	1085	20.06	34.2	203	187	105	89	82)

Table 3. Yield table for unmanaged white spruce plantations (site index 18)

Age from planting years	Dominant height (m)	Average height (m)	Planted spacing (m)	Trees per ha (no.)	Mean d.b.h. (cm)	Basal area/ha (m^2)	Volume/ha Total (m^3)	Volume/ha Merch (m^3)	Mass/ha Total tree (t)	Mass/ha Total stem & bark (t)	Mass/ha Merch stem & bark (t)
20	7.2	5.5	(1.25	6014	6.60	20.6	63	22	26	22	8)
			1.50	4285	7.37	18.3	55	24	23	20	9
			1.75	3217	8.08	16.5	50	24	21	18	9
			2.00	2496	8.74	15.0	45	25	19	16	9
			(2.50	1600	10.00	12.6	37	24	16	14	9)
			(3.00	1111	11.13	10.8	32	22	14	12	8)
25	9.4	7.2	(1.25	5570	8.08	28.6	111	64	48	40	23)
			1.50	4026	9.01	25.7	99	62	43	36	23
			1.75	3074	9.88	23.6	90	63	39	33	23
			2.00	2427	10.68	21.7	82	61	36	31	23
			(2.50	1600	12.24	18.8	70	58	31	27	22)
			(3.00	1111	13.75	16.5	61	53	28	23	20)
30	11.6	8.9	(1.25	5036	9.53	35.9	168	118	74	63	44)
			1.50	3680	10.63	32.6	150	110	67	57	42
			1.75	2854	11.60	30.2	138	109	62	53	42
			2.00	2296	12.49	28.1	127	104	58	49	40
			(2.50	1581	14.18	25.0	111	98	52	44	39)
			(3.00	1111	15.94	22.2	98	89	46	39	35)
35	13.7	10.8	(1.25	4450	11.00	42.3	228	178	106	90	70)
			1.50	3291	12.24	38.7	206	165	97	82	66
			1.75	2600	13.28	36.0	189	159	90	77	65
			2.00	2120	14.26	33.8	176	151	85	72	62
			(2.50	1523	15.98	30.5	157	140	77	65	58)
			(3.00	1111	17.79	27.6	140	129	69	59	54)

Table 3. (cont'd)

Age from planting years	Dominant height (m)	Average height (m)	Planted spacing (m)	Trees per ha (no.)	Mean d.b.h. (cm)	Basal area/ha (m^2)	Volume/ha Total (m^3)	Volume/ha Merch (m^3)	Mass/ha Total tree (t)	Mass/ha Total stem & bark (t)	Mass/ha Merch stem & bark (t)
40	15.5	12.4	(1.25	3900	12.40	47.1	282	231	135	115	94)
			1.50	2945	13.69	43.4	256	215	125	106	89
			1.75	2355	14.81	40.6	237	204	117	99	85
			2.00	1960	15.79	38.4	222	193	110	94	82
			(2.50	1446	17.56	35.0	200	180	101	86	77)
			(3.00	1099	19.30	32.1	181	167	92	79	73)
45	16.8	13.7	(1.25	3530	13.46	50.3	322	270	160	135	113)
			1.50	2690	14.81	46.4	293	249	147	125	106
			1.75	2174	15.99	43.6	273	238	139	118	103
			2.00	1825	16.99	41.4	256	225	131	112	99
			(2.50	1380	18.74	38.1	233	212	121	103	94)
			(3.00	1077	20.42	35.3	213	196	112	95	87)
50	18.0	14.9	(1.25	3194	14.51	52.8	358	304	183	155	132)
			1.50	2464	15.92	49.1	328	282	170	144	124
			1.75	2009	17.11	46.2	306	269	160	136	120
			2.00	1703	18.14	44.0	289	254	152	129	114
			(2.50	1314	19.86	40.7	264	240	141	119	108)
			(3.00	1051	21.49	38.1	245	225	132	112	103)
55	19.0	15.9	(1.25	2920	15.45	54.8	388	330	202	171	145)
			1.50	2278	16.87	50.9	356	310	188	159	138
			1.75	1868	18.12	48.2	333	293	178	151	133
			2.00	1600	19.14	46.0	316	281	170	144	128
			(2.50	1257	20.84	42.9	291	265	158	134	122)
			(3.00	1025	22.39	40.4	271	249	149	126	116)
60	19.8	16.7	(1.25	2710	16.25	56.2	412	350	218	185	157)
			1.50	2120	17.74	52.4	379	330	203	172	150
			1.75	1762	18.95	49.7	356	313	193	163	143
			2.00	1520	19.97	47.6	338	301	184	157	140
			(2.50	1210	21.65	44.5	313	285	173	147	134)
			(3.00	996	23.17	42.0	292	269	163	138	127)

Table 4. Yield table for unmanaged white spruce plantations (site index 21)

Age from planting years	Dominant height (m)	Average height (m)	Planted spacing (m)	Trees per ha (no.)	Mean d.b.h. (cm)	Basal area/ha (m^2)	Volume/ha Total (m^3)	Volume/ha Merch (m^3)	Mass/ha Total tree (t)	Mass/ha Total stem & bark (t)	Mass/ha Merch stem & bark (t)
20	8.4	6.4	(1.25	5820	7.40	25.1	88	43	44	37	18)
			1.50	4160	8.28	22.4	78	44	39	33	19
			1.75	3148	9.08	20.4	70	44	35	30	19
			2.00	2467	9.83	18.7	64	43	32	27	18
			(2.50	1600	11.28	16.0	54	42	27	23	18)
			(3.00	1111	12.62	13.9	47	39	24	20	16)
25	11.0	8.5	(1.25	5175	9.14	34.0	152	102	76	65	44)
			1.50	3774	10.19	30.8	135	96	68	57	40
			1.75	2920	11.13	28.4	124	95	62	53	41
			2.00	2340	11.99	26.4	114	91	57	49	39
			(2.50	1591	13.65	23.3	99	86	50	42	37)
			(3.00	1111	15.38	20.6	87	79	44	37	34)
30	13.6	10.7	(1.25	4477	10.94	42.1	226	176	113	96	75)
			1.50	3312	12.15	38.4	203	162	102	86	69
			1.75	2613	13.19	35.7	186	154	93	79	66
			2.00	2137	14.16	33.6	174	148	87	74	63
			(2.50	1526	15.89	30.3	155	138	78	66	59)
			(3.00	1111	17.71	27.4	138	127	69	59	54)
35	15.9	12.8	(1.25	3790	12.72	48.2	295	245	148	126	105)
			1.50	2867	14.02	44.3	267	224	134	114	96
			1.75	2298	15.16	41.5	247	212	124	105	90
			2.00	1918	16.16	39.4	233	205	117	99	87
			(2.50	1426	17.91	35.9	210	191	105	89	81)
			(3.00	1093	19.66	33.2	191	176	96	81	75)

Table 4. (cont'd)

Age from planting years	Dominant height (m)	Average height (m)	Planted spacing (m)	Trees per ha (no.)	Mean d.b.h. (cm)	Basal area/ha (m^2)	Volume/ha Total (m^3)	Volume/ha Merch (m^3)	Mass/ha Total tree (t)	Mass/ha Total stem & bark (t)	Mass/ha Merch stem & bark (t)
40	17.9	14.8	(1.25	3230	14.40	52.6	355	302	178	151	128)
			1.50	2480	15.82	48.7	324	279	162	138	119
			1.75	2022	17.02	46.0	303	267	152	129	114
			2.00	1715	18.04	43.8	286	252	143	122	107
			(2.50	1320	19.78	40.5	261	238	131	111	101)
			(3.00	1053	21.40	37.9	242	223	121	103	95)
45	19.5	16.4	(1.25	2782	15.95	55.6	402	342	202	171	145)
			1.50	2180	17.41	51.9	371	323	186	158	137
			1.75	1804	18.63	49.2	348	306	174	148	130
			2.00	1551	19.64	47.0	330	294	165	141	125
			(2.50	1227	21.35	43.9	304	277	152	129	117)
			(3.00	1009	22.85	41.4	284	261	142	121	111)
50	21.0	18.0	(1.25	2414	17.50	58.1	446	379	224	190	161)
			1.50	1917	19.02	54.5	413	359	207	176	153
			1.75	1606	20.24	51.7	388	341	195	165	145
			2.00	1403	21.25	49.8	371	330	186	158	141
			(2.50	1139	22.89	46.9	346	315	173	147	134)
			(3.00	960	24.30	44.5	325	299	163	138	127)
55	22.1	19.2	(1.25	2148	18.79	59.6	476	405	239	203	173)
			1.50	1817	19.95	56.8	449	391	225	191	166
			1.75	1536	21.19	54.2	425	374	213	181	159
			2.00	1302	22.48	51.7	401	357	201	171	155
			(2.50	1075	24.06	48.9	376	342	189	160	146)
			(3.00	921	25.41	46.7	356	328	179	152	140)
60	23.2	20.5	(1.25	1928	20.07	61.0	506	430	254	215	183)
			1.50	1572	21.61	57.7	473	412	237	201	175
			1.75	1349	22.83	55.2	449	395	225	191	168
			2.00	1202	23.79	53.4	432	384	217	184	171
			(2.50	1010	25.29	50.7	406	369	204	173	157)
			(3.00	880	26.57	48.8	388	357	195	165	152)

Table 5. Yield table for unmanaged white spruce plantations (site index 24)

Age from planting years	Dominant height (m)	Average height (m)	Planted spacing (m)	Trees per ha (no.)	Mean d.b.h. (cm)	Basal area/ha (m^2)	Volume/ha Total (m^3)	Volume/ha Merch (m^3)	Mass/ha Total tree (t)	Mass/ha Total stem & bark (t)	Mass/ha Merch stem & bark (t)
20	9.7	7.4	(1.25	5500	8.28	29.6	118	70	51	43	25)
			1.50	3980	9.23	26.6	105	68	46	39	25
			1.75	3048	10.11	24.5	96	68	42	36	25
			2.00	2413	10.92	22.6	88	66	39	33	25
			2.50	1600	12.51	19.7	75	63	34	29	24
			(3.00	1111	14.07	17.3	66	58	30	25	22)
25	12.6	9.8	(1.25	4780	10.20	39.1	196	147	89	75	56)
			1.50	3500	11.38	35.6	176	136	81	69	53
			1.75	2740	12.39	33.0	162	131	75	64	52
			2.00	2219	13.33	31.0	150	126	70	60	50
			2.50	1557	15.04	27.7	132	117	63	53	47
			(3.00	1111	16.85	24.8	117	108	56	48	44)
30	15.5	12.4	(1.25	3900	12.40	47.1	282	231	135	115	94)
			1.50	2945	13.69	43.4	256	215	125	106	89
			1.75	2355	14.81	40.6	237	204	117	99	85
			2.00	1960	15.79	38.4	222	193	110	94	82
			2.50	1446	17.56	35.0	200	180	101	86	77
			(3.00	1099	19.30	32.1	181	167	92	79	73)
35	18.2	15.1	(1.25	3146	14.68	53.3	365	310	187	159	135)
			1.50	2425	16.11	49.4	333	286	173	147	126
			1.75	1983	17.29	46.5	311	274	163	138	121
			2.00	1684	18.32	44.4	294	259	155	132	116
			2.50	1309	20.03	41.3	270	246	144	123	112
			(3.00	1047	21.66	38.6	250	230	135	115	106)

Table 5. (cont'd)

Age from planting years	Dominant height (m)	Average height (m)	Planted spacing (m)	Trees per ha (no.)	Mean d.b.h. (cm)	Basal area/ha (m^2)	Volume/ha Total (m^3)	Volume/ha Merch (m^3)	Mass/ha Total tree (t)	Mass/ha Total stem & bark (t)	Mass/ha Merch stem & bark (t)
40	20.5	17.5	(1.25	2540	16.97	57.5	433	368	233	198	168)
			(1.50	2000	18.46	53.6	398	346	217	184	160)
			(1.75	1673	19.70	51.0	375	330	207	176	155)
			(2.00	1450	20.70	48.8	357	318	198	168	150)
			(2.50	1170	22.36	45.9	332	302	187	158	144)
			(3.00	977	23.82	43.5	312	287	177	150	138)
45	22.3	19.4	(1.25	2118	18.99	60.0	483	411	270	229	195)
			(1.50	1706	20.52	56.4	448	390	254	216	188)
			(1.75	1452	21.74	53.9	425	374	243	206	181)
			(2.00	1283	22.72	52.0	407	362	234	199	177)
			(2.50	1063	24.28	49.2	381	347	221	188	171)
			(3.00	916	25.61	47.2	363	334	212	180	166)
50	24.0	21.4	(1.25	1775	21.09	62.0	528	449	308	261	222)
			(1.50	1457	22.63	58.6	494	430	291	247	215)
			(1.75	1265	23.81	56.3	471	414	280	237	209)
			(2.00	1133	24.77	54.6	453	403	271	230	205)
			(2.50	967	26.19	52.1	429	390	259	220	200)
			(3.00	850	27.43	50.2	411	378	249	212	195)
55	25.3	22.9	(1.25	1548	22.82	63.3	561	477	336	285	242)
			(1.50	1293	24.34	60.2	528	459	320	271	236)
			(1.75	1136	25.49	58.0	505	444	308	261	230)
			(2.00	1033	26.38	56.5	489	435	299	255	227)
			(2.50	897	27.74	54.2	466	424	288	244	222)
			(3.00	804	28.84	52.5	449	413	279	237	218)
60	26.5	24.4	(1.25	1363	24.51	64.3	590	502	364	309	262)
			(1.50	1155	26.02	61.4	558	485	348	295	257)
			(1.75	1030	27.10	59.4	536	472	336	285	251)
			(2.00	945	27.96	58.0	522	465	328	279	248)
			(2.50	836	29.21	56.0	500	455	317	269	245)
			(3.00	760	30.22	54.5	484	445	309	262	241)

Table 6. Age at which mean annual increment culminates

Item	Site Index Class	Spacing Class (m)					
		1.25	1.50	1.75	2.00	2.50	3.00
Total volume	15	50	50	50	50	50	50
	18	50	50	50	50	55	55
	21	45	50	50	50	50	50
	24	40	45	45	50	50	50
Merch volume	15	55	50	50	50	55	50
	18	50	50	50	55	55	55
	21	45	50	50	50	50	50
	24	40	45	45	50	50	50
Total biomass	15	50	50	50	50	-	-
	18	55	55	55	55	-	-
	21	50	55	-	-	-	-
	24	50	50	50	-	-	-
Total stem plus bark	15	50	50	50	50	-	-
	18	55	55	55	55	-	-
	21	50	55	55	-	-	-
	24	50	50	-	-	-	-
Merch stem plus bark	15	55	55	-	-	-	-
	18	50	55	55	-	-	-
	21	50	55	55	-	-	-
	24	50	50	-	-	-	-